

# THE ROLE OF PROXIMITY IN AUTOMOTIVE TECHNOLOGY SUPPLY CHAIN DEVELOPMENT: AN INTRODUCTORY ESSAY<sup>1</sup>

Charles Fine, George Gilboy, Kenneth Oye, and Geoffrey Parker<sup>2</sup>

Massachusetts Institute of Technology  
Cambridge, Massachusetts 02139

Working Draft. Please do not cite without permission.

May 1995

## 1. Introduction: Production and Place

Regional economic development and economic geography are compelling issues for students of political economy, management and public policy because they frame the question of production and place. The study of production and place lies at the heart of issues central to the rise and fall of great powers and great enterprises: international politics and trade, technology development, and the organization and management of production. Production and place are also central to the lives of individuals: they determine the nature of work, the rise and fall of living standards, and in large part, local politics. From the level of the nation-state to the level of the individual, the story of production and place is the story of the quality and quantity of jobs.

People live close to where they work. They spend money close to where they live. They contribute their taxes, skills and knowledge to their communities. The sum of their wealth and capabilities largely determines their attractiveness as a community to new investment, and new people. Wealth and capabilities also determine a community's influence in interactions with other communities. Thus, the location of large numbers of high quality jobs is both the result of, and the cause of, prosperity and autonomy.

Nations, states, and regions compete for prosperity and autonomy. In part, they do so because the effect of economic competition raises everyone's absolute welfare by forcing economic agents to constantly improve their capabilities, goods, and services. But nations, states and regions also compete for relative prosperity and autonomy. Nations compete for wealth and security, because the international system is anarchic, and each nation must rely on its own resources to maintain its existence and living standards. States and regions also compete with one another, each hoping to maximize its relative standard of living, in part to continue the

---

<sup>1</sup>Financial support for this project from within MIT--Leaders for Manufacturing, the International Motor Vehicle Program, the Industrial Performance Center, the International Center for Research on the Management of Technology, and the Japan Program--as well as from Chrysler, Intel, Sematech, and Texas Instruments, is gratefully acknowledged.

<sup>2</sup>Fine and Parker are in the Sloan School of Management; Gilboy and Oye are in the Political Science department.

process of raising living standards, but also to maximize autonomy relative to the central government, and relative to other states and regions.

The competition for prosperity and autonomy, then, is often competition for the location of production. It is a competition for the quantity and quality of jobs. This project seeks to identify some of the principal factors that lead to success in this competition for regional economic development. Our guiding questions are simple, yet applicable across a wide range of issue areas: when does the place of production matter? How is the place of production determined?

This essay is divided into the following sections: in section 1.1, we briefly argue that the auto industry is a compelling case for studying regional economic development and economic geography precisely because it generates large numbers of high-quality jobs, and forges tight linkages to production and jobs in upstream and downstream sectors. In section 2, we present the issues of production and place more systematically. Having established the importance of the issue of production and place in this introduction, we move on to frame the debate by defining two types of “space” over which public and private authorities have jurisdiction, and across which production and its attendant jobs are (re)located. We further define four types of proximity: geographic, organizational, cultural, and electronic, that plausibly contribute to the success of economic development. These kinds of proximity offer varied incentives and disincentives for industrial agglomeration, and therefore inspire competition between nations, states and regions for the location of production and jobs. Also in section 2, we introduce two issues that have remained largely unexplored in the literature on regional economic development and economic geography: the strategic interaction between and among firms and public authorities, and the question of production technology development and sourcing.

## 1.1 The Case: The Auto Industry and Production Technology

The automobile industry generates thousands of jobs, both in the actual assembly of autos, and in the parts, equipment, and service industries that are linked to it. In the U.S., approximately 6.7 million people were employed in the auto industry and its supply and service sectors in 1991. Manufacturing employment in the industry comprised an estimated 1.2 million people, or 6.5% of all manufacturing jobs in 1991. Shipments of autos and equipment amounted to \$236 billion in 1992, or about 16% of the value of all manufactured goods. Because of its size, both in terms of revenue generated and jobs created or tightly linked to it, the auto industry is an excellent case for studying the question of production and place, and the competition between and among firms and nations for prosperity and autonomy. Moreover, the auto industry exerts a significant “demand pull effect” on manufacturing technology, as assemblers and parts makers seek new ways to build and assemble many, constantly shifting, auto components. This makes the industry ideal for developing an understanding of the role of production technology supply chains in the causes and consequences of regional economic development and economic geography.

### 1.1.1 Production Technology

Manufacturing technologies are deployed, problem-solving knowledge systems, often (but not exclusively) embodied in machines. These technologies are the implements with which firms produce goods. The quality, productivity,

efficiency, reliability and capability of manufacturing equipment are central determinants of the competitiveness of manufacturing firms, because the implements themselves impose limits on the quality and cost of the goods they produce, and limits on the kind of goods that can be produced.

Consider the following hypothetical question: is it preferable to develop a new manufacturing system with an independent company (that may also service competitors) that is located across the street, or is it preferable to develop the new system with a division of your own company that is located overseas. Of course the answer is, "it depends..." But depends on what? The cost of transporting goods and knowledge, Acme's organizational coherence, the nature of the relationship with the supplier in example "1.)", Acme's own conception of its "core capabilities", the effectiveness of in-house Acme's electronic communications, the complexity of the technology under development — all of these matter. These are many of the same issues that have been explored for components supply. However, these same issues may produce different outcomes when the product to be supplied is manufacturing technology, rather than components.

Manufacturing equipment industries offer fertile ground for exploring the relationship between technology development, economic geography, regional economic development and politics. The argument for manufacturing equipment as a critical case for theories of management, public policy and political economy (and the link between political economy and international politics) has three elements: technological, economic, and political.

The technology argument contends that advances in manufacturing process technology have widespread general effects on all manufacturing activities in the economy. Further, innovations directly benefit manufacturers. Successful innovations in manufacturing technology and its use also spur widespread imitation, thus providing indirect benefits to many other firms. Moreover, the equipment sector is a good place for innovation to happen, because it interacts with all manufacturers. Equipment suppliers can function as the "clearing houses" of manufacturing innovation. For example, the development of NC technology increased the ability of manufacturers to perform small-lot production, furthering the potential of both the "lean" and "agile" production paradigms. In this way, manufacturing equipment technology development can strongly influence the nature and course of regional economic development and the organization of work.

The complexity of many manufacturing technologies offers a critical test for some theories of economic geography. The need to exchange design and development information frequently and extensively, the possibility of benefits from informal and spontaneous information exchange, and the need to maintain the equipment and resolve difficulties associated with its design, manufacture, installation and operation all seem to indicate that, *ceteris paribus*, firms will prefer to develop manufacturing technology in close proximity to one another.

The economic argument for the study of manufacturing equipment is as follows: *ceteris paribus*, manufacturing equipment makers operate in perhaps the most hostile economic environment of any industry. Cyclicity in the machine tool industry, for example, is extreme. Recent scholarship has established that a firm's position in the industrial "food chain," affects the nature of the cycle it faces.<sup>1</sup>

---

<sup>1</sup>See Anderson, Fine, Gilboy, and Parker, "Upstream Volatility in the Supply Chain: The Machine Tool Industry as a Case Study," MIT working paper, May 1995 and J. D. Sterman,

[Sterman, 1989]. The further “back” in the chain a firm is, the greater the probability that it will have difficulty interpreting economic signals, and the greater the likelihood that it will suffer for the cumulated effects of cyclical ordering from other firms further along the chain. Moreover, capital equipment makers face other problems that militate towards greater cyclicity. When a recession looms, expensive capital equipment investments are the first orders to be cut. But when a recovery takes place, capital equipment orders can increase dramatically. For example, if a tire plant wants to make 20% more tires, it will buy 20% more labor and raw materials. If the factory normally replaces 10% of its equipment in a year, then a 20% increase in production may triple the normal amount of equipment the factory orders from its suppliers.

This cyclicity has several negative effects. It often means that there are fewer resources to devote to research and development. This leads to a reduced ability to innovate, leaving some equipment makers vulnerable to competitors. Extreme cyclicity also weakens equipment makers by interrupting cash flow and profitability. And cyclicity discourages skilled workers from entry into the industry, causing the loss or disuse of skills and capabilities and interfering with the development of new technology. Thus, the equipment sector has special economic difficulties that must be managed. A political-economic coordination mechanism that can manage this extreme cycle and its negative consequences may be able to mitigate less extreme difficulties in other industries. On the other hand, political-economic coordination mechanisms that can manage other economic problems, as “lean” production manages the problem of components supply, may not be sufficient to address the difficulties of equipment supply.

Many of the coordination mechanisms that have been observed or proposed to mitigate the negative effects of cyclicity depend on “trust.”<sup>1</sup> The joint commitment of assets, and the extension of aid or assistance from prime contractors to suppliers engender joint vulnerabilities. These vulnerabilities are acceptable only when both parties to the transaction feel secure that the other will not exploit them. They must trust one another. But is this kind of trust possible only within certain geographically limited economic and socio-political boundaries? Most of the current literature claims this is the case. Here again we have the requirements for a critical case study.

The political argument about the importance of the manufacturing equipment sector begins with the premise that political jurisdictions have geographic boundaries. Geography is political, and vice-versa. The case then rests on a series of arguments about the sources of relative regional and international prosperity and autonomy. In this argument, national economic prosperity relies heavily on manufacturing industry, not only for employment, but also because it is tightly linked to service industries that employ even more people. Moreover, manufacturing industries are also the key source of innovation in society, generating economic change and growth, as well as generating new solutions to social and political problems. Further, national security relies heavily on manufacturing industry, because only industrial manufacturers can supply the hardware implements of war. Manufacturing industry, in turn, relies heavily on

---

“Modelling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment,” *Management Science*, (35) 3: 321-339, March, 1989.

<sup>1</sup> See, for example, Charles Sabel, “Learning by Monitoring,” MIT 1993.

equipment technology as source of competitive advantage, and the basis for production possibilities. Political authorities have an interest in relative regional and international prosperity and security. Further, the development and diffusion of manufacturing technology is encouraged or constrained by prevailing political-economic institutions.<sup>1</sup> Methods of managing the extreme cyclicity of the manufacturing equipment industry are made possible or are precluded by prevailing political economic institutions, and the role of public authorities in manufacturing equipment industry appears to be pervasive; witness the “voluntary” restraints on machine tool imports. This means that manufacturing equipment industries are a critical case for testing theories of business-government relations: the stakes for the state appear to be high, state influence is often pervasive, and political-economic rules and standards set limits on, and offer incentives for, economic choices within geographic boundaries.

## 2.0 Jurisdictional Boundaries and Strategic Interaction

Nations, states, regions and enterprises have a singular feature in common: they are bounded “spaces.” These spaces form jurisdictions: organizational entities, either public or private, charged with maximizing the interests of the community over which they have authority. Nations, states and regions have *geographic* boundaries to their authority, reflecting the limits of their power and influence. Enterprises have *organizational* boundaries. Enterprises use these boundaries in much the same way that nations, states and regions do: they attempt to maximize benefits within them, and minimize risks and costs to the organization by keeping undesirable elements outside the boundaries of the organization.

We propose to investigate the effects of three kinds of *proximity* on technology supply chain *location* and *performance*. Geographic proximity is simply physical closeness. Organizational proximity refers to the structure of and intensity of linkages between economic agents. Electronic proximity refers to the form of and intensity of electronic communication between economic agents.

Transnational enterprises relocate production and its attendant jobs in response to market opportunities and the costs of production. Firms try to maximize advantages of capital, technology, labor skills, local markets, while minimizing costs such as those of liability and regulation, labor, transportation costs, and taxation. In other words, enterprises move production across both geopolitical and organizational space in order to maximize benefits and minimize costs. A substantial (and varied) literature on transnational corporations and economic geography has explored some of these issues [See Walker, 1989; Modelski et al, 1979; Krugman, 1991]

An improvement to the literature on production and place has come from exploring other stimuli to firm location decisions: in addition to concerns for the cost of regulation and labor, some observers have noted that enterprises transfer the location of production in response to the quality and cost of components supply [Womack et al, 1990; Smitka, 1991; Nishiguchi, 1994; Kenney and Florida, 1992].

---

<sup>1</sup> See, for example, Richard J. Samuels, *Rich Nation, Strong Army*, Ithaca: Cornell, 1994, See also, Max Holland, *When the Machine Stopped*, Cambridge: Harvard Business School Press, 1989, and MIT Commission on Industrial Productivity, *Made in America*, Cambridge, MIT Press, 1989.

These observers argue that *proximity*, both in geographical and organizational terms, is a central feature of successful components supply relationships. Components supply, then, is a powerful incentive to regional economic agglomeration, and the concentration of many high quality jobs.

Yet important weaknesses in the literature on regional economic development and the politics of production and place remain. First, little has been done to explore the ways public authorities respond to the moves of firms as they relocate production and jobs. How do nations, states, and other regulatory authorities respond to the transfer of production across jurisdictional boundaries? Some may attempt to chase enterprises across geo-political boundaries by asserting extra-territoriality of law and regulation. Some may attempt to use taxation or regulation to encourage or discourage the transfer of production and jobs across geo-political boundaries.

Regulatory outcomes from political processes may serve to mitigate or reinforce the economic effects of proximity, because regulatory outcomes tend to be unique within the geographic boundaries of nation-states. On the other hand, technology supply strategy and preferences may influence firms' behavior in political debates about regulation, and may affect the outcome of regulatory debates. While firms seek to minimize costs and maximize benefits within geographic boundaries because they must suffer the authority and jurisdiction of public authorities. It is a central contention of our project that firms will try to use regulation to exclude competitors from certain markets, or to gain other advantages relative to competitors. Firms pursue varied strategies for dealing with regulation: they may try to subvert the intent and effects of regulation, or try to use it to advantage, or have to conform to it. Meanwhile, public authorities will use their resources to pursue their interests as firms attempt to move production and jobs across geo-political boundaries.

As yet, only dim light has been shed on the strategic interaction between firms, between firms and public authorities, and between public authorities as they all vie to maximize prosperity and autonomy, often through the location and re-location of production and jobs. One possibility is that the interaction between public authorities and firms may blur the boundaries between both. Or perhaps the competition will prove the durability and rigidity of geo-political and organizational boundaries. We suspect that the pattern of regional economic development that emerges from this strategic interaction will, in any case, be more complex than the pattern we might predict without consideration of political and economic strategy and competition across jurisdictions.

Second, while the extant literature has developed an increasingly clear picture of incentives to location decisions, important factors have been largely ignored. For example, some observers have explored the cost of waste disposal and environmental regulation, the cost of labor, the cost of capital, and the role of taxation, as well as the cost and quality of components supply. Yet the literature has failed to explore the issue of production technology supply. The development and sourcing of production technology is a central element of competitiveness. The quality, productivity, efficiency, reliability and capability of manufacturing equipment are central determinants of the competitiveness of manufacturing firms, because the implements themselves impose limits on the quality and cost of the goods they produce, and limits on the kind of goods that can be produced. Table 1 shows that most studies on economic geography have been done in the area we call

supply logistics. This refers to the development, production and transfer of components and other inputs to production. Our own focus is on the area of technology supply.

We suggest that technology supply is by definition more complex than logistical supply. Each component is itself the product of one or more processes of one or more steps. Developing these processes and the equipment to carry them out is a complicated and problem-laden undertaking. Problem solving among discrete economic agents requires communication. We expect to find greater “communications intensity” requirements as we move from studying logistics to technology development. Even within the area of technology development, we expect to find greater communications intensity as we move from studying product to process development.

Perhaps geographic and organizational proximity will emerge as a central factor in successful technology supply relationships. Perhaps the need for geographic and organizational proximity may be mitigated by the rise of *electronic integration* (another way of saying *electronic proximity*) between and among public and private authorities. Again, we suspect that the pattern of regional economic development and the location of production and jobs will emerge as more complex when we consider the development and sourcing of production technology. We argue that including the issues of strategic political-economic interaction and the development of production technology will improve our understanding of the causes and consequences of economic geography.

Below, we further develop the notions of geographic, organizational and electronic proximity, and their effects on the location of production. In the final section, we develop at length our proposal for studying the role regulatory authorities, firms, regulation, and regional economic development

**Table 1: Proximity, Technology Supply Chains and Political-Economic Regulation**

	FIRM DECISIONS		GOV'T DECISIONS
<u>Proximity</u>	<u>Supply Logistics</u>	<u>Technology Supply</u> (Product-Process)	<u>Regulation</u>
Geographic	Transportation economies  [Isard] [Krugman]	Fundamentals: • Labor concentrated • Transport econ. • Information flows more easily	Political jurisdictions have geographic boundaries
Organizational	Large firm/small location choices  [Watts]  Transaction cost economies/production system  [Lean: Kenney-Florida]	Substitutes geographic proximity?  Conforms to/takes advantage geographic imperatives  [Friedman; Herrigel]	for Subverts regulation: (Transplants still source equipment from "home")  of Follows regulation: (firms pressured to open transplants)
Electronic	EDI  [Orlicky]	Substitutes geographic organizational proximity?  Design distinct from problem resolution  [Students of IT]	for Subverts regulation: Canada and internet pornography  Follows regulation: (U.S. NTIS and standards setting network)



## 2.1 Geographic Proximity

Recent research has identified a dual locational trajectory in the automotive industry: a simultaneous trend towards both globalization and regionalization. On the one hand, recent years have seen a significant amount of automotive production move to new locations. On the other hand, automotive production remains characterized by significant regional clusters and agglomerations of production activity in the U.S. industrial heartland, the Tokyo and Nagoya regions of Japan, and the Baden-Württemberg region in Germany. New plants have been opened in many of these traditional strongholds.

The automotive industry has been characterized by a high degree of regional concentration of agglomeration since its inception. During the early years of the industry's development, regional agglomeration was seen to be the result of proximity to key supplies and raw materials, such as steel, and transportation economies. In recent decades, it was believed that advances in transportation and communication technology made regional concentration less important, and that the automotive sector--like other sectors--would undergo a considerable degree of geographic dispersion. In fact, during the 1970s and 1980s, a number of auto-makers developed international production strategies, referred to variously as world car or southern strategies. Such strategies, it was argued, were the result of auto-makers seeking new competitive advantages through lower costs of production, lower wages, construction of new greenfield plants and more flexible work environments.

The past decade or so has seen the rise of a new conundrum--the simultaneous globalization and regionalization of industrial activity. At first it was thought that globalization would diminish the importance of regional clusters. But, the prominence of regional industrial clusters in the national and international clusters during the 1980s and continuing into the 1990s confounded that view in rather fundamental ways. It thus appeared that globalization did not necessarily undercut the importance of regional clustering. In fact, a number of analysts began to advance the notion that regionalization and globalization might be complementary rather than contradictory modes of industrial and geographic organization.

While all the answers are certainly not in, it appears that regional agglomerations offer a number of advantages to firms located within the cluster. The classic benefits stem from external economies of scale and scope and from network externalities, that is sufficient scale in a particular industry or product line, or sufficient breadth of firms in related or similar product lines. External economies tend to arise from the local character of many types of knowledge (R&D, technology, labor skills, and more general social capabilities) that are rooted in the region, and stem in part from the local production of specialized inputs to a particular industry--for example, the specialized skills and expertise embodied in human capital and supportive institutional structures. Firms in the region learn from one another, and supportive infrastructures grow up from which these firms draw. Spillovers are facilitated by both formal and informal interactions among organizations and individuals in the region. Such regional specialization of this sort involves the development of specialized skills in the labor force, specialized institutions, specialized infrastructures, and more serendipitous spillovers of knowledge between and among organizations. In fact, it may be this kind of regional specialization--local concentrations of knowledge, ideas and more general social

capability--and not proximity to raw materials and markets which accounts for the regional concentration of economic and industrial activity over time.

On a global scale, the automotive industry may be taking the form of global localization with the development of regional clusters of production linked to global sourcing and marketing strategies. Regional clusters in the automotive industry differ in fundamental respects from the small firm agglomerations identified by both Alfred Marshall and Piore and Sabel. Regional clusters in the automotive industry appear to take the form of what might be called hub-spoke agglomerations consisting of complexes of suppliers surrounding a central hub or anchor assembly facility. In such agglomerations, the central hub firm--along with its primary suppliers--plays a key role in organizing and reorienting the entire production chain. This organizing function takes numerous forms including: development of production standards, performance review, technology transfer and diffusion, joint involvement in new product development, longer term contracting, technical assistance, equipment sharing, and personnel exchange.

We focus on the regional dimensions of the global automotive industry, and be organized around the following questions. To begin, we examine the economic geography of the automotive industry, developing detailed maps of the automotive sector on a global scale. These maps will enable us to identify key clusters of automotive production and design and technology development activity. We will then turn our attention to the key factors that shape these regional and geographic issues. What are the key factors in the locational decisions of automotive assemblers and suppliers? When is proximity important, and why? What are the critical factors that determine geographic closeness? Does this differ by component across the value chain? Does the role of proximity decline over time? That, has critical level of learning occurred such that geographic closeness is less important now than it was in the past? Are only the suppliers of non-critical components moving south to peripheral locations? Is it more important for firms to have "black-box" suppliers or "build-to-print" suppliers in close proximity? All of this adds flesh to the question of why and how proximity matters.

There are a number of business strategy and public policy implications that flow rather immediately from this work. First, if regional concentration is a clear imperative, free trade agreements like the NAFTA ought not to be feared on the ground of job displacement; rather, such agreements may well reduce the incentive for a southern shift, since manufacturers can eventually ship their product without impediment into Mexico. On the other hand, if NAFTA's passing has actually sped the flight of automotive manufactures to the south, what does that mean for the theory and reality of regional clustering?

All of these issues are critical for regional economic development and for national policy as well. If attracting an assembly plant guarantees that a swarm of suppliers will follow, than it may be quite rational for states to give subsidies to lure these hub facilities. On the other hand, if suppliers chase low wages, other strategies may make sense. If some suppliers go toward low wages and others must be close to assemblers, then regional governments must consider what mix of companies they should try to attract. Furthermore, regional clusters of production, knowledge and social capability may require fundamentally different infrastructures than previously. A lean production or knowledge-creating region is likely to be as different from a traditional mass production region, as Toyota is from General Motors.

## 2.2 Organizational Proximity

The question of the production and place of manufacturing technology may depend not only on the incentives of geography, but also on the goals and behavior of organizations. Organizations seek to maximize benefits and minimize costs. In an earlier section, we posed a hypothetical question that suggested that organizational proximity could be a substitute for geographic proximity, and vice versa. In this part of our research, we hope to expand our understanding of the relationship between organizational and geographic proximity as it bears on decisions about production and place. Thus, we will explore firm decisions across a variety of incentives and disincentives to (re)locate production and jobs, in the context of production technology supply. These issues include:

- Firm strategy and self-conception
- Supplier relations form:
  - Market/Hierarchy/Cooperative-competitive
- Technological complexity
- Autonomy/dependence
- Formal and informal knowledge transfer

## 2.3 Electronic Proximity

We also ask whether electronic integration can substitute for physical or organizational proximity. Perhaps the substitutability of electronic proximity for physical or organizational proximity will vary by technology: for example, video conferencing may be a better substitute than electronic mail. Electronic integration may serve to mitigate or reinforce the effects of other variables. For example, it may reduce the need for physical proximity. Or, it may be unable to replace key features of close physical and/or organizational proximity (for example, veterans of the “conference call” know its strengths and limitations).

On the other hand, it may reinforce the effects of geographically-limited public policy. As an example of the latter, the U.S.-government, the form of the National Technical Information Service, is operating a manufacturing technology standards setting program and electronic data integration program that is only open to U.S. companies. In a counter-example, we note that electronic integration is subverting policy in the case of internet-based pornography, and in the global matter of software piracy.

We hypothesize that under some circumstances, electronic proximity may act as a substitute for either physical proximity or organizational proximity, or both. As information technology (IT) improves, will the economic costs of geographic and organizational distance fall significantly? Williamson does not discuss geographic distance in his theories of transaction costs and vertical integration. Is this a hole in the transaction cost literature?

For some observers, there are two critical phases in manufacturing: design and production.<sup>1</sup> During design there is a strong need to communicate to establish requirements and ways of meeting them (product or process requirements). During production (or ramp-up) there is a strong need to communicate for the purpose of problem-solving. Design could be done electronically, meaning that there are no

---

<sup>1</sup> In our presentation of this section, we have benefited greatly from discussions with Dan Whitney. Any deficiencies, however, are our own.

requirements for geographic proximity. The issue is not the means of communication but the matters that are communicated and the computer tools that permit those matters to be dealt with analytically: tolerances, interface definitions, performance requirements, etc. On the other hand, there are phases of design that involve intensive negotiations, and these usually must be done face to face. so it is not a clear thing.

Problem solving may be another matter. Perhaps personal contact is needed here because the problems are unexpected and unstructured. Diagnosis is difficult and finger-pointing has to be avoided. But once the problems are solved it seems that work can go on, especially if the manufacturer has in-house capability.

#### 4. Methodology

We plan to undertake comparative case studies of body assembly equipment for major auto assemblers and their equipment suppliers. We propose to conduct both statistical analyses and qualitative analysis from critical case studies. We are developing a comprehensive questionnaire that treats many of these issues from the point of view of equipment technology development. This questionnaire can be adapted to the study of economic geography as well. We will supplement the data from the questionnaires with archival research. In this way, we hope to generate inferences based on the large view, but to supplement and qualify those inferences with intensive case studies of individual firms and sectors.

So, for example, we will gather data on electronic proximity that measures characteristics such as: percentage of components and manufacturing equipment designed on Computer-Aided-Design software, software compatibility among departments and between organizations, and level of electronic technology: from phone, to fax, e-mail, and at the higher end of electronic integration, video conferencing. These variables will be compared with data on physical proximity and organizational proximity: physical location and organizational "maps." To complete the picture, we will gather data on equipment and technology access, quality and performance, and some limited data on cost. These data will be tied together by careful description of other variables such as technology strategy, organizational strategies, autonomy/dependence analysis, and other factors that develop during focused case studies.